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SINCGARS-V MATURITY OPERATIONAL TEST: HUMAN FACTORS EVALUATION (SYNOPSIS)

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

ARI, Ft. Hood, TX, conducted the human factors evaluation of the preproduction "Advanced Development Model" of the SINCGARS-V receiver/transmitter (RT). The evaluation was part of the Maturity Operational Test of the system conducted by OTEA at Ft. Riley, KS, September - December 1983. The RT was found to have numerous human factors problems. The most notable were in the areas of the complexity of operational procedures, the physical design of the control panel, the inadequacy of the cue function, system documentation, and the excessive training requirement. The report includes suggestions for hardware and software design changes and stresses the necessity for operational simplification.

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FOREWORD

Pursuant to a Letter of Agreement between the Army Research Institute (ARI) and the US Army Operational Test and Evaluation Agency (OTEA) (15 June 1983), the ARI Field Unit at Fort Hood, Texas provides human factors evaluations of selected Army systems tested under the auspices of OTEA.

The research reported here was a human factors evaluation of the preproduction SINCGARS-V radio (Advanced Development Model) conducted in conjunction with OTEA's Maturity Operational test of the system at Ft. Riley, Kansas during the fall of 1983. This report condenses the original ARI report (R. L. Palmer [ARI], and S. E. Bowser, L. Avery, R. Sawyer, and J. Cotton [Essex Corp.], SINCGARS-V Maturity Operational Test: Human Factors Evaluation [U]), which appeared as an unclassified section of the OTEA Test Report (SINCGARS-V Maturity Operational Test [U], Test Report [FTR-OT-280A], US Army Operational Test and Evaluation Agency, March 1984, SECRET). This synopsis also provides additional information concerning operator retention of training, which was not available when the OTEA test report was published.

SINCGARS-V MATURITY OPERATIONAL TEST: HUMAN FACTORS EVALUATION (SYNOPSIS)

EXECUTIVE SUMMARY

Requirement

The human factors evaluation of the preproduction SINCGARS-V Advanced Development Model (ADM) was conducted by the Army Research Institute (Fort Hood Field Unit) to determine whether the human factors aspects of the ADM were adequate for operational performance and safety.

Procedure

The human factors team made detailed equipment inspections, observed operator-equipment interaction, and systematically solicited observations, opinions, and comments from all key personnel, including all operators. Data were collected by direct observation, data collection forms, interviews, and investigation of field problems as they occurred. System features were also assessed in accordance with the human factors standards set forth in MIL-STD-1472C. The operator-radio interface design (including operational procedures) was closely examined and evaluated by contrasting it with a potential design incorporating many hypothetical changes. Also evaluated was the retention of operator skills and knowledge over time.

Major Findings

1. OPERATING PROCEDURES were complex and inconsistent, making them difficult to learn and retain. They require excessive operator vigilance and training.

2. The CONTROL PANEL was complex, crowded, unreliable, easily abused, and difficult to read from non-central viewing angles and in low light. The inherent limitations of the LED display (five seven-element characters) caused the display prompts and feedback to be cryptic and difficult to remember.

3. RELIABILITY AND MAINTAINABILITY were inadequate in several areas, including documentation, tools, and procedures.

4. The RECONFIGURABILITY of the system (vehicular to manpack, etc.) was associated with logistic and operational problems pertaining to the lithium battery, cabling, antenna connections, manpack carrying frame, and vehicular mounts.

5. The CUE FUNCTION was extremely prone to false cue indications, causing operators to ignore it completely.

6. INSTALLATION AND CABLING for the antennas, speakers, and other associated communication equipment were not well configured or trained.

7. SYSTEM DOCUMENTATION for training, operation, maintenance, installation, and cabling was inadequate.

8. There was considerable doubt among the operators' supervisors and test directorate personnel that the typical radio operator would have the SKILLS required to adequately perform the roll of NCS. Operators and directorate personnel estimated that about two weeks of SINCGARS ADM TRAINING would be necessary to train the average NCS operator.

9. Key test directorate personnel and operator supervisors tended to be opposed to replacing the current inventory of radios with the SINCGARS ADM. They felt that the Army would benefit greatly from additional advanced development of SINCGARS and subsequent testing.

Utilization of Findings

The human factors evaluation upon which this synopsis is based was conducted in conjunction with the US Army Test and Evaluation Agency (OTEA) Maturity Operational Test of the SINCGARS-V ADM, September - December 1983. The original human factors evaluation report was published as a section of the OTEA Test Report (FTR-OT-280A), March 1984, and provided input to OTEA's Independent Evaluation Report. It was also made available to the SINCGARS Project Manager, the TRADOC Systems Manager, and the developer, and has provided the basis for significant changes in the SINCGARS system. Some of these changes were incorporated into a "Modified Advanced Development Model," which was subsequently evaluated during the fall of 1984. Other changes are scheduled for incorporation into the final production model.

SINCGARS-V MATURITY OPERATIONAL TEST: HUMAN FACTORS EVALUATION (SYNOPSIS)

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SINCGARS-V MATURITY OPERATIONAL TEST: HUMAN FACTORS EVALUATION (SYNOPSIS)

INTRODUCTION

This document presents the human factors (HF) evaluation findings for the preproduction SINCGARS-V ADM receiver/transmitter. The HF evaluation was conducted by the Army Research Institute, Fort Hood Field Unit, and was part of the SINCGARS-V Maturity Operational Test (MOT) conducted at Ft. Riley, Kansas (September - December 1983) by the U.S. Army Operational Test and Evaluation Agency.

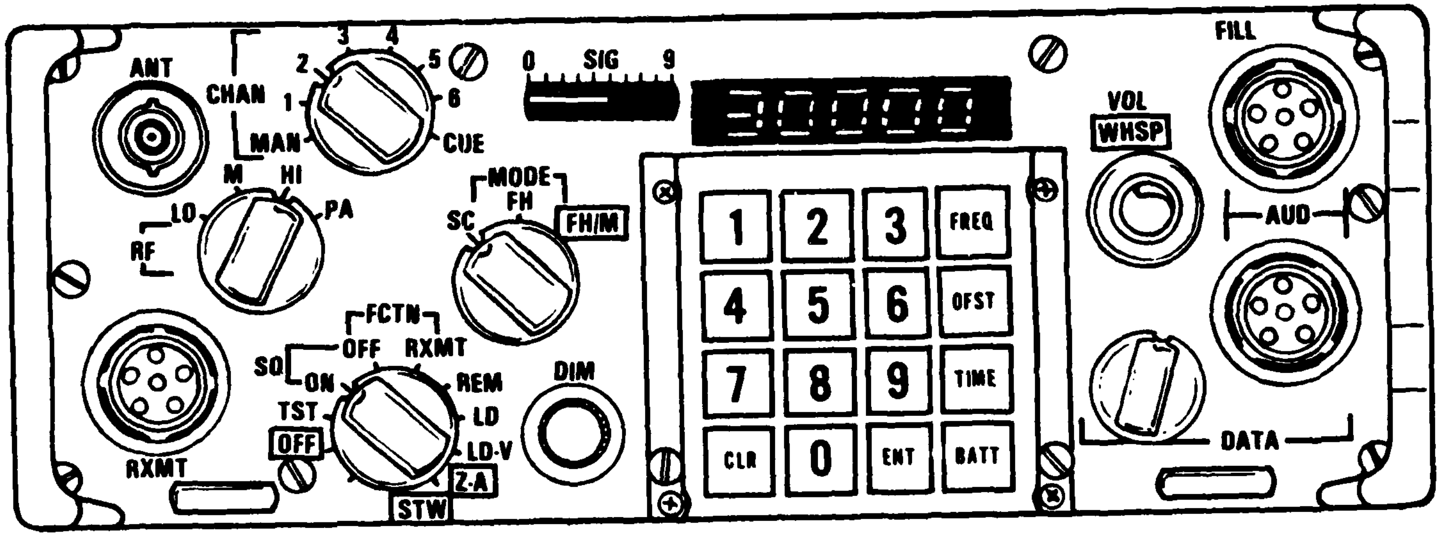
OPERATIONAL DESCRIPTION OF THE SYSTEM

SINCGARS-V ADM (Single Channel Ground/Airborne Radio Subsystem - VHF, Advanced Development Model) is actually a multi-channel VHF-FM receiver/-transmitter (RT). It is manufactured by the Aerospace/Optical Division of the International Telephone and Telegraph Corporation and is intended to replace the current VRC-12 and PRC-77 VHF-FM communication equipment. Features of the system include the following: small, lightweight, portable construction; push-button tuning; frequency-hopping capability; digital data transmission at selectable rates; retransmission capability; channel scanning; seven vehicular and manpack configurations; low power consumption in the battery-powered manpack configuration; and selectable power outputs (up to 50 watts with power amplifier). A view of the RT's front panel is shown in Figure 1.

Selection of the operating function is divided among five selector switches and six dedicated key switches. Numerical data is entered through a key pad (0-9). The five-character, seven-bar LED display works in conjunction with three of the function switches and the keyboard. Its brightness is varied by a front panel control. A signal strength indicator is provided to indicate the relative power of received and transmitted RF signals. A pull-out switch concentrically mounted with the volume control allows the operator to whisper into the handset microphone without communication degradation.

The RT has eight frequency channels and conventional VHF-FM capability. One of the eight channels is used as a primary administrative channel (or "manual" [MAN] channel, as it is called), and a second channel is used to "CUE" the net control station (NCS) to switch to the MAN channel. During initial fielding, SINCGARS-V compatibility with existing VHF-FM communication equipment can be maintained through this conventional channel arrangement.

The outstanding feature of SINCGARS-V is that it is designed to "hop" randomly among different VH frequencies during transmission and reception, which provides an anti-jamming, anti-direction-finding capability. The hopping is made possible by a microprocessor-controlled digital tuning mechanization. This technique requires that the variables for the frequency hopping (FH) algorithm be loaded into the RT from any one of several external loading



SCALE – 3/4" = 1"

Figure 1. SINCGARS-V Advanced Development Model. Front Panel.

devices and methods. The loading device can be connected directly to the RT or data-linked (transmitted) to each SINCGARS-V net member by the NCS. The data-link capability is not necessarily protected by the FH feature, but it can be accomplished while in that mode. Exact time synchronization (plus or minus a few seconds) must be continuously maintained among all RT's within the same net.

PURPOSE AND SCOPE OF THE EVALUATION

The HF evaluation was conducted to determine whether the HF aspects of the SINCGARS-V (ADM) are adequate for operational performance and safety. To this end an assessment was made of the physical layout of the RT control panel; the operating procedures; the operational suitability of switches and controls; the visibility of switches, controls, and displays with normal illumination, blackout lighting, and bright sunlight; noise levels; equipment size and weight; operation with (and without) NBC MOPP gear (level 4), adverse weather equipment, and night vision goggles. Emphasis was on identifying soldier-machine interface problems and assessing implications for effective mission performance from a human engineering standpoint. In addition, an attempt was made to identify any safety or health hazards related to the use of SINCGARS-V equipment.

The HF criterion for SINCGARS-V was stated in the MOT Test Design Plan as follows: "Must meet the human engineering factors specified in MIL-STD-1472C, Human Engineering Design Criteria for Military Systems, Equipment and Facilities under Operational Mission profiles as described in the Doctrinal and Organizational Test Support Package and specified in the SINCGARS-V Specification DS-AF-0200C, amendment No. 2, 15 January 1979 under operational conditions." The HF team attempted to identify all instances in which SINCGARS-V failed to comply with the stated MIL-STD criterion or with other principles of good HF design and practical operability.

Also evaluated were the SINCGARS operational skills and knowledge levels exhibited by operators after SINCGARS training, after practice in a field exercise setting, and after intervals of non-use.

METHOD OF EVALUATION

General Design of the Maturity Operational Test

Just prior to the MOT, all of the radio operators had recently received refresher training on general radio operation procedures, using current-inventory ("baseline") radios. The MOT itself consisted of four phases: training; pilot test; field exercise test; and a reliability and maintainability (RAM) exercise.

In phase 1, all of the radio operators received one week of formal classroom training on SINCGARS followed by one week of informal unit training in which both SINCGARS and baseline radios were employed.

Phase 2, which followed immediately, was a one-week pilot test conducted in the field. The pilot test was designed to match closely the actual field exercise test to follow. Both SINCGARS and baseline radios were used during the pilot test.

In phase 3, three field exercise tests were conducted. Two of the tests--a one-week simulated battalion task force exercise followed by a one-week simulated tactical operations center exercise--were conducted with cavalry soldiers. The other test--a one-week simulated direct support battalion exercise--utilized artillery soldiers.

In phase 4, the cavalry soldiers, after a two-week layoff, used the SINCGARS RT in a two-week RAM exercise. Thus the total amount of SINCGARS experience across all four phases of the MOT was 4 weeks for the artillery soldiers and 7 weeks for the cavalry soldiers. It is important to note that the SINCGARS experience for both groups was intensive and probably considerably more concentrated than that of most future SINCGARS users.

HF Evaluation Techniques

The HF team consisted of a systems engineer and four human factors engineering psychologists. During the MOT the team made detailed equipment inspections and observations of operator-equipment interaction, and systematically solicited observations, opinions, and comments from the operators ("players"), maintenance personnel, field data-collection personnel, test directorate staff, instructors, and the operators' supervisors. The information was collected by formal and informal interviews, direct observation, questionnaires and other data-collection forms, and investigation of field problems as they occurred. The evaluation included references to MIL-STD-1472C where applicable.

HF Assessment Instruments

Thirteen questionnaires and a retention exam were administered to various groups of respondents at various times. The questionnaires were not entirely independent: In order to establish trends, differences, and confirmations, many items were presented to respondents more than once and often appeared in more than one questionnaire in identical or slightly modified form.

The assessment devices and the methodology utilized in each are described in the following list.

1. Attitude Check: A single-item attitude questionnaire was given to cavalry and artillery operator-trainees at the beginning of the TRADOC-administered SINCGARS operator training course and again following the midterm exam. The purpose was to evaluate the effect of the training upon attitudes (and vice versa) and to assess the possible effects of favorable or unfavorable attitudes upon field-test performance.

2. Evaluation Survey Questionnaires: These were comprehensive instruments administered to SINCGARS operators at the end of the training course and again following the field testing. Most of the questions were multiple choice with five-alternative, bipolar, evaluative response scales. The objective was to assess operator attitudes about all aspects of the system

and system support: the RT itself, the technical manual, operating procedures, ease of operation, reliability, the training course, etc. In addition to the response scales, most of the items contained space for comments.

3. Data Collector Human Factors Forms (P500 and P500A): Human factors data-collection forms were given to OTEA data collectors throughout the course of both the cavalry and artillery field testing. Although human factors was not the focus of the data collectors' task, much of what they could observe was closely related to the various human-performance issues. These forms were highly condensed (especially P500A, a revision of P500) and were used in the field. The data collector was required to submit a P500 or P500A after each operator workshift.

4. Supervisors' Questionnaire: This questionnaire was given to NCO's and officers overseeing the field exercises in order to obtain their perspective on the SINCGARS equipment, maintenance, reliability, and other issues bearing upon the operation of the RT under field conditions.

5. Retention Test: All operators were given a two-part retention test. One part, ("Knowledge") was geared to the types of questions in the TRADOC SINCGARS-V training exams. The second part ("Skills") was an exercise in which the operators ran through a desk-top simulation of various operating procedures. The artillery operators were tested after training and again shortly after the MOT field exercise test. The cavalry operators were tested after the field exercise test and again after a three and one-half week period during which the RT was not used. A subsample of both groups was tested again after six months.

MAJOR FINDINGS

1. OPERATING PROCEDURES were complex and inconsistent, making them difficult to learn and retain. They require excessive operator vigilance and training.

2. The CONTROL PANEL was complex, crowded, unreliable, easily abused, and difficult to read from non-central viewing angles and in low light. The inherent limitations of the LED display (five seven-element characters) caused the display prompts and feedback to be cryptic and difficult to remember.

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9. Key test directorate personnel and operator supervisors tended to be opposed to replacing the current inventory of radios with the SINCGARS ADM. They felt that the Army would benefit greatly from additional advanced development of SINCGARS and subsequent testing.

DETAILED FINDINGS (Section 1: System Operation)

Operating Procedures

1. The MAN channel frequency can be loaded in the SQ ON, SQ OFF, and LD positions of the function selector. Allowing alternate switch settings for the same function is a marginal design practice. The operation should be allowed in one position only.

2. Loading the FH TRANSEC and lockout variables during a local fill requires the channel selector to be in the MAN position. "MAN" connotes single channel (SC) operation; it is confusing to mix this label into FH operations. Multiple use of a switch setting for different function purposes is a marginal design practice.

3. The TRANSEC variable is an integral requirement for FH operation. Having to load the TRANSEC variable with the mode switch in the SC position rather than the FH or FH/M position is inconsistent. Each switch position should be made to conform to the overall purpose of the operation involved.

4. In the FH mode the keyboard is used to select which lockout set or hopset is to be "purged." In the SC mode the channel selector switch is used. Having multiple procedures for the same type of operations is marginal design practice. There should be one operationally consistent purging procedure for both SC and FH data.

5. Multiple pressing of OFST, CLR, and ENT keys is required to enter, send, or purge various data (e.g., frequency offset, negative offset, ERF data). This requires the operator to remember a "hidden" operation for selected keys and circumstances. Requiring the multiple use of the same key for an operation is questionable design practice, especially when combined with an absence of feedback to the operator. Such practices create operator errors. In the same problem area, the use of a single key for multiple purposes is acceptable only so long as labeling and displays inform the user.

In general, the procedures would be improved by providing better feedback to the operator on the current status of the RT and what functions are currently active. Multiple pressing requirements should be eliminated so that each key is pressed only once to accomplish the desired function.

6. Using the OFST key for sending the ERF is unrelated to the advertised use of the key. A special key or switch position should be provided for sending ERF data to net members.

7. Pressing CLR to clear the display prior to entering data is an unnecessary step. The internal operation should be changed so that the display is automatically cleared each time a digit key is pressed. (Most calculators have this feature.)

8. Normal keyboard entries are made by pressing the sequence FCTN-CLR-digit-ENT. For the ERF, however, the sequence is Digit-CLR-ENT. The use of two procedures for clearing and entering is operationally inconsistent. The procedure should be redesigned so that clearing and entering are always accomplished the same way.

9. When the operator attempts a voice transmission with the DATA switch out of the "off" position, no feedback indicating this condition is provided. Software controlled procedures should alert the operator when switches are not in correct positions for normal communications.

10. Both frequency offset and battery amp-hrs are always displayed as two digit numbers; however, an offset of five must be entered as a single "5," but five amp-hrs as "05." The entry of information into the RT should be done in the same sequence whenever possible and, if possible, should be the same as similar operations on commonly used equipment. Furthermore, using the keyboard to enter numbers and function would be beneficial because that would employ the same procedures as the common small calculators with which most potential users have had experience.

11. The lockout set cannot be verified after entry without the fill device connected unless the mode switch is placed in the FH/M position and the data retrieval procedure commenced. Entered data should be verifiable at all times without entering the FH/M mode. Data verification is basic to good operator interface design. This capability should be easier to use in the RT.

12. ERF data is sent to net members in increments; and in a late net entry, up to two lockouts and up to six hopsets are sent with the RT in the SC mode. Each set of data requires a preamble transmission from the NCS and a verification transmission from each net member. The exposure time to jamming and direction finding is substantial. The NCS operator should have the option of sending lockouts, hopsets, and time to net members as a single transmission. The incremental sending of FH variables may be a capability that should be maintained; however, the system would be improved if the ERF could be accomplished in one data transmission. The prime control of this data and its location in the net member's RT should be given to the NCS.

The net control should be able to preselect storage locations and communication variables for both SC and FH operations.

13. After ERF data has been received by the net member, it must be stored promptly; otherwise, the next ERF transmission will overwrite the holding memory, destroying the previous data. Operational and software safeguards should be introduced to prevent the possible destruction of transmitted or stored data.

14. The FH data in the RT is supposed to be controlled by the NCS to ensure that all net members conform to the same communication variables. However, individual net members can purge FH data. The purging process requires either that the RT be completely zeroized or that one of the fill devices be used. The purging process by individual net members is complex and subject to error. The procedural requirement for net members to purge FH data should be eliminated. This would reduce errors and save communication time. When the net controller ERF's new FH data, it should be stored by either a simple one-step operation or an automatic write-to-memory.

15. Minutes and seconds, although functionally related in the RT, cannot be viewed by the operator at the same time. This increases complexity for the NCS (and net members receiving time transfers) because the display has to be switched alternately to keep a check on the minute count. Loading and display procedures for date and time should be modified so that minutes and seconds are displayed together.

16. The seven-second cutoff of the time display (except when holding the TIME key depressed--an inconvenience) necessitates repeated pressing or holding of the TIME key. The result is operator frustration during network time synchronization. The distraction associated with the requirement for holding down the time key contributes to the poor net time synchronization problem. The concept of a display cutoff should be reevaluated for vehicle-mounted RT's. This function does not seem to be necessary except in the manpack configuration.

17. Loading FH information into the RT memory is complicated. Fill devices used for FH are loaded via a paper tape system designed to support VINSON. Tapes for FH data are up to six feet long and are pulled through a reading device by hand. This method seems impractical for field use. Procedural errors in the loading process are frequent, with subsequent loss of FH communication. Loading procedures should be automated as much as possible, especially at net member stations. The supporting devices used to input data into the RT should be reviewed and an integrated approach devised.

18. The use of multiple devices to enter data into the radio memory is confusing and creates logistics problems. The number of fill devices should be reduced to one, with one fill position for all FH data entry.

19. In order to prevent electrical damage and memory loss in the fill device KYK-13, it should be turned off before being attached to or detached from the RT. This requirement seems unrealistic for field operations. The

interface between the RT and fill devices should be designed to prevent transients regardless of the on/off status of the device or the RT.

20. There is virtually no feedback to the operator when an entry or function selection error has been made. E.g., when multiple presses of the same key are required, no feedback for intermediate presses is provided. Operating procedures should be redesigned to make greatest possible use of the display to indicate system status. Increased alpha display capability is desirable.

21. The use of a sound ("beep") to confirm some operations is a problem in noisy environments, which may mask the "beep." Redundancy of signals (e.g., a sound plus a display message) may be desirable.

22. The LD and LD-V positions on the FCTN switch may be redundant. They should perhaps be combined.

23. When the FCTN switch is in the OFF position, the memory-holding battery may be drained if the RT is not isolated (i.e., if the applique is not turned off) when the vehicle is started. Current Army doctrine and training require the RT, not the applique, to be turned off. The circuit protection for the holding battery should be corrected to insure integrity of the holding battery when the vehicular applique is on.

24. The RT software is not "user friendly" and performs no automatic self tests for operational and data inconsistencies (e.g., time check). The RT software should be redesigned to help the operator detect operational and data inconsistencies that affect communications.

25. A generally reported problem was that operators had difficulty locking the various RT connectors into their receptacles. This problem results from the limited space for connectors. The layout of the RT exterior should be carefully reviewed for space allocation. Even small increases of space for space consuming procedures would be helpful.

26. Current procedures will result in the failure to log (or incorrect logging of) battery status. The sharp drop-off in the battery power curve may cause RT operation to fail unexpectedly because no warning of imminent battery failure is given. The RT battery power system should be designed so that a warning of imminent battery failure is possible.

27. The term "amp hours" and the amp-hour scale (1 to 17) used in logging battery life is judged to be overly technical and not especially meaningful to the RT operator. A decimal scale, such as 1 to 10 or 1 to 100 is suggested. It should indicate battery life <u>remaining</u>, rather than <u>used</u>, and should denote operating time remaining under specified operating circumstances (e.g., type of duty cycle).

28. If battery life is not recorded prior to zeroizing the RT, current battery status is lost. The RT should be redesigned so that battery status is retained while working on a battery and when the RT is zeroized.

29. The clips used to attach the battery to the RT unit became insecure with use and were difficult to access to ensure good security. In general, the battery pack is difficult to secure to the RT. The method of attaching the battery to the RT should be redesigned for easier use and greater security.

Control Panel

30. The LED display is recessed into the RT front panel so that visual angles greater than about 20 degrees above or below center cut off part of the display. Placement of the RT lower than the operator's eyes seems to be the greater problem. The cut-off of the display, especially from above, resulted in almost a two-hour delay in communication in one field incident. The display should be changed so that it can be accurately read from viewing angles up to 45 degrees.

31. The seven-bar LED display cannot configure a complete alpha-numeric character set. Hence, messages must conform to this limitation, which causes cryptic and difficult-to-understand messages and prompts. Consideration should be given to alternative displays (e.g., nine-bar, or 7 x 9 dot matrix). The display limitation contributes to the "user unfriendliness" of the RT and its software. A means should be created to provide meaningful prompts in a visual form to the operator.

32. The red LED display is hard to read in bright sunlight. Consideration should be given to changing the display to a type and/or color that is easier to read and use under a variety of ambient light conditions. The readability of red LED displays is a known problem, and their use is questionable for a radio that is to be used in a manpack configuration.

33. The RT was designed without panel lighting. Hence, when the unit is mounted in a vehicle (the most common use), the lettering on the panel is difficult to read, which is conducive to operator error. The control panel should be lighted for vehicle operations, with the level of illumination adjustable. For manpack operation, the lighting could be disabled. A very low-level panel and keyboard light may be more detection-secure in night operations than the use of red-filtered flashlights.

34. The lettering on the control panel is not reflective and is not readable with night vision goggles, in either the passive or the active mode, while outside on a dark night. The lettering on the RT control panel should be reflective and easier to read in ambient light, both with and without night vision equipment.

35. The control panel is so crowded that individual controls were not discernable in a night operation using passive night vision goggles. The configuration of controls on the control panel should be reviewed for visibility and improved where possible.

36. The position of the display dimmer control makes it prone to accidental change without operator awareness. The control turns too easily; its

resistance should be increased so that accidental touching does not alter its position.

37. Error free operation of control knobs is almost impossible with thermally insulated gloves. Operation of the RT with gloves was accomplished by using pencils, pens, and other available items to depress the keys. The lack of durability of key labeling was probably associated with this practice. The knob shapes and spacing should be altered to comply with MIL-STD-1472C.

38. The size of the keyboard keys is borderline for large fingers, especially when wearing thermally insulated gloves. This makes error free data entry difficult. Key shape/size should be changed (e.g., raise the keys 3/16 inch above escutcheon plate and taper them from the base upwards).

39. Keys with multiple functions are not identified (labeled) for functions performed, an unnecessary complication. Keys that have multiple functions should be clearly labeled for all functions.

40. The front panel is cluttered by having too much designed into insufficient space. This leaves little space for appropriate labeling. This problem could be alleviated to some extent by improving the labeling and perhaps eliminating unessential labels such as FCTN, CHAN, MODE, and RF.

41. The volume control moves too easily, which makes it prone to accidental change without the operator's awareness. Resistance to movement should be increased so that accidental touching does not alter its position.

42. The labeling on the data selector switch is hard to read. The paint wears off, and the markings become invisible. The markings on the switch should be engraved, filled, and sealed.

43. The handset can be used in either connector on the right side of the control panel unless the DATA switch is on, in which case the lower connector will not work. If the operator is unaware that the DATA switch is on (a possibility enhanced by obscure labeling on the switch), and the handset is plugged into the lower connector, communication will be impossible. The labeling on the right side of the front panel needs improvement to eliminate confusion about the purpose of the AUD/FILL/DATA reception.

44. On some of the RT's the protective detent for the Z-A position on the FCTN switch could be inadvertently overridden, causing loss of communication data. The detent needs to be strengthened to prevent accidental loss of data from memory.

45. If the RT is used in subzero temperatures, certain operations (e.g., connecting antenna and data transmission cables) may require the removal of gloves because of the close proximity of connectors, front panel guards, and other controls. Under such conditions, skin exposure and skin-metal contact may cause injury to the operator. The front panel should provide easy access to all plugs, knobs, and keys for operators wearing thermally insulated gloves.

46. SC controls are intermixed with FH controls. Operation of the RT as a SC radio is complicated by the confusion of controls and their functions. FH and SC controls should be grouped apart to facilitate operator training and use of the RT as a SC radio.

47. The antenna connector on the face of the RT tends to become loose. It is extremely difficult to tighten because of its proximity to the panel guards. The front panel design should insure that the antenna connector can be easily tightened if it becomes loose.

48. Keyboard function buttons were difficult to operate after extended use. Operators compensated by pushing harder, often with pencils and the like. The key surfaces were seriously damaged. The keyboard should be more durable.

Reliability and Maintainability

49. Excessive amounts of "on-the-air" time were required to resolve RT performance and reliability problems stemming from the loss or desynchronization of time, interference from collocated or connected VHF-FM equipment (including collocated SINCGARS-V RT's), and RT memory loss from power transients. Operators should be required to minimize the number and length of transmissions.

50. The interior of the RT (circuit cards and test points) is not adequately labeled. Identifying labels should be put on all circuit cards and test points.

51. The removal of circuit cards requires a special tool. The tool, which is not standard Army issue, comes stored in the back of each RT. The tools are easily lost, and without them the circuit cards cannot be removed without probable damage. A requirement for special tools or devices not in regular inventories promotes logistic insupportability of the RT. The circuit card removal mechanism should be changed or the tool required to be standard issue.

52. The circuit cards, especially the ECCM module, do not always stay seated in the parentboard. The interior of the RT should be redesigned to secure the cards to the parentboard and aid in the removal of the card.

53. There are no keys to prevent incorrect insertion of modules or circuit cards. Keys that preclude improper insertion of modules or cards should be incorporated.

54. Removal of switch module A304 requires the prior removal of the two-wire interface A303, or damage to a capacitor can result. The RT interior should be redesigned to obviate this requirement.

55. The circuit cards are static electricity sensitive, requiring the maintainer to use a wrist-worn grounding strap. This strap can be easily lost and not used because of its inconvenience. Consequently, the maintenance of circuit cards is hampered. The sensitivity of circuit cards to

static electricity should be eliminated or counteracted in a manner that does not complicate maintenance procedures.

56. The vehicular applique lacks structural guides to aid in installing the RT. This can lead to improper seating of the RT in the applique. Guides should be incorporated into the applique.

57. The RT self-test generates "FAIL" messages with a high degree of false alarms. This results in unnecessary maintenance removals of inservice units. False alarms also result in operators learning to ignore the feature. The built-in-test feature of the RT should be designed to preclude the occurrence of false-fail indications.

System Reconfiguration

58. Regarding the manpack-to-vehicle conversion, it was unclear during the MOT who was responsible for logging battery life and stowing the battery. Also, there were no designated places in the various vehicles for stowing the battery. These problems could be ameliorated by appropriate training.

59. If two vehicles are intercabled for retransmission purposes, the configuration could be rendered unserviceable in an emergency evacuation if the cabling were not disconnected. In such situations, quick-break connectors should be available for the cabling.

60. In some cases, intravehicle cabling for the MOT was not kept short or stowed properly. Such cabling can become a physical hazard. The cabling layout for each vehicular configuration should incorporate layout specifications designed to minimize physical hazards, inconveniences, and maintenance problems.

61. In a vehicular mount, the cabling between the VINSON device and the RT has to be turned through 90 degrees in a small space. This and the lack of finger space around the RT's J5 and J6 connectors makes cable installation and change difficult. The mechanical design of the cable interface between the RT and other devices for each vehicle configuration (including such configurations as TACFIRE) should be changed to alleviate the small space problems to the extent feasible.

62. The antenna connection used in the MOT protrudes so far from the front panel of the RT that it is a physical hazard, especially in the 1/4 ton vehicle. The antenna connection should conform to standard vehicle installation and use L-connectors where required.

63. To properly work as a manpack RT, the SINCGARS-V requires a new or redesigned carrying frame. A redesigned frame was tested in the MOT and found to be inadequate for the following reasons: (a) The operator could not adequately tighten the RT in the frame to prevent bouncing during walking running, and crawling. (b) The operator could not raise his head when in the prone position because of the crossbar at the frame top. (c) The DMD cannot be mounted on the bottom shelf. A different frame is needed.

64. The vehicular applique has positions for two RT's. However, if only one RT is installed, the lower position must be used or power surge damage to the RT may result. The applique should be redesigned to eliminate power surge problems.

Cue Function

65. The cue display is too easily triggered, and the NCS operator therefore learns to ignore it. These erratic cues are triggered by unknown causes (outside interference) not attributable to net member action. Cue sensitivity to outside causes should be eliminated so that operators can rely on the important operational service that the cue function should provide.

66. The display of "CUE" in all radios with the same cue frequency is a distraction for net members because it is meant only for NCS operators. The requirement to attend to "CUE" as an NCS but not as a net member is poor operational procedure. The cue message should be enabled only for SC-to-FH communications and only for those operators who are to respond. It is recommended that the cue display be active only for NCS and alternate NCS operators. The cue function could be enabled by the FM/M switch and otherwise be inactive.

67. The six-second keying of the handset to trigger the cue function is too long in an emergency situation. It is proposed that a different type of signal (e.g., pulsed or tone) and/or a shorter time be used to trigger the display. The method must be compatible with current RT's.

68. During the MOT field exercise tests, the CUE frequencies of different nets overlapped, resulting in confusion. The assignment of CUE frequencies should be properly integrated with Army frequency management doctrine.

Installation and Cabling

69. The installation of two RT's with a single speaker causes confusion and operational problems. Appropriate vehicle installation procedures should be determined.

70. Procedures for vehicular cabling and interconnecting SINCGARS-V with communication and computer equipment are not well defined. The critical parameters of vehicle installation and cabling should be reviewed and the relevant information incorporated in manuals and training to minimize the problem.

71. Without external speakers, vehicle mounted RT's suffer from a potential loss of incoming messages. Each RT deployed in a vehicle should have an external speaker. Ideally, the speaker would be an integral part of the vehicular applique.

System Documentation

72. The maintenance manuals (DEP-11-5820-890-20 and 30) contained textual inaccuracies, errors, and insufficient information. They require substantial editing and rewriting to provide more complete and accurate information.

73. The operator's training and field manual was unacceptable in many ways: The index was wholly inadequate; the use of color in the manual was inconsistent, illogical, and confusing; illustrations were often complicated, unclear, or unnecessary; text was wordy, repetitive, and sometimes ungrammatical; and layout and organization were cumbersome. Operators need a simple, straightforward "how-to-do-it" manual expressed clearly and simply and in a manner that is not overly personalized.

DETAILED FINDINGS (Section 2: Retention of Training)

During the MOT, an attempt was made to obtain a rough measure of the retention of operator skills and knowledge over short intervals during which the SINCGARS either was or was not used. One group of operators (the artillery soldiers) were administered SINCGARS skill and knowledge exams at the end of MOT phase 1 and again (parallel forms) just after phase 3. One would normally expect their skill levels to increase somewhat during the interval as a consequence of practice. The change in knowledge, however, is more difficult to predict. It could conceivably decrease as the amount of time since training increases. Furthermore practicing operator skills during the interval could interfere with retention of the more strictly knowledge aspects of the training.

Table 1 shows the results for this group of operators. Surprisingly, skills and knowledge both appeared to decrease somewhat. It may be that the simulated nature of the skills test caused it to be a measure of knowledge as well as skills. If so, the skill and knowledge subtests would be expected to yield similar results, which is what happened.

The table also shows results for five artillery soldiers who, while they had received the same SINCGARS training as the rest of the group, did not use the SINCGARS RT at all after their training was completed. They used the baseline RT instead. The baseline operators apparently suffered a greater loss of SINCGARS skills than the SINCGARS group, as expected. However, they seemed to lose less SINCGARS knowledge. While the number of individuals involved in these comparisons is very small and there was no control over many potentially influential variables, this finding is not necessary inconsistent with the hypothesis, mentioned above, that practicing SINCGARS skills may have interfered with the retention of SINCGARS knowledge. The baseline operators were considerably more idle throughout the field test exercise than the SINCGARS operators; hence SINCGARS knowledge gained in the classroom may have decayed more slowly because of a lack of subsequent interfering activity.

Table 1

Skills and Knowledge Retention

(Artillery Soldiers after Three Weeks Practice)

Test	RT	N	Admin. #1[a]	Admin. #2[b]	% Change
Skills	SV	29	84.0	79.7	- 5.1
	BL	2	79.8	65.9	-17.4
Knowledge	SV	27	83.8	79.1	- 5.6
	BL	3	72.5	69.9	- 2.6

[a]Percent correct after classroom training.
[b]Percent correct after field exercise test (after three weeks of practice, not including training).

The cavalry soldiers were administered the same skill and knowledge exams as the artillery soldiers. However, the first administration was not conducted until phase 3 (the field exercise test) was over. The second administration occurred about three and a half weeks later. During the interval, the soldiers performed normal duties within their unit and experienced no contact with the SINCGARS and probably little or no contact with the baseline RT. Results for this group are shown in Table 2. Both skill and knowledge levels were expected to decrease for both SINCGARS and baseline operators, which appears to have happened, at least for the baseline operators. The levels for SINCGARS operators may also have decrease somewhat, but apparently very little.

Several things should be noted here: First, at the end of the field exercise test (first administration) the cavalry operators had had approximately four weeks of SINCGARS or baseline practice since their SINCGARS classroom training, as opposed to the artillery soldiers who had had only three weeks of practice. If, indeed, the practice of SINCGARS (or baseline) skills interfered with knowledge retention, one would expect the cavalry knowledge scores to be lower than the artillery knowledge scores. Table 2 shows this to be the case. However, since the artillery and cavalry groups were not comparable in several ways, this finding could be compatible with other hypotheses as well.

Table 2

Skills and Knowledge Retention

(Cavalry Soldiers after Four Weeks Practice and Three and One-Half Weeks Layoff)

Test	RT	N	Admin. #1[a]	Admin. #2[b]	% Change
Skills	SV	24	80.6	78.4	- 2.8
	BL	4	68.2	58.6	-14.1
Knowledge	SV	23	69.8	69.4	- 1.0
	BL	4	63.8	55.1	-13.6

[a]Percent correct after field exercise test (four weeks practice, not including training).

[b]Percent correct three and one-half weeks later with no intervening practice.

Second, the first administration for the cavalry took place at a time comparable to the second administration for the artillery; i.e., after the field exercise test. Since the cavalry operators had had more practice than the artillery operators at this point in time, their skill scores should be somewhat higher than those of the artillery group, all other things equal. The tables show a small tendency in this direction. One can only hypothesize that the difference would be greater if the groups had been matched on relevant variables (e.g., GT scores---the average GT score for the artillery group was somewhat higher than for the cavalry group).

Third, the decrement for baseline operators, who had no SINCGARS practice, was apparently larger than that of the SINCGARS operators, as expected. This group is perhaps most representative of the expected user population in the sense that many users will probably not operate SINCGARS continually, but will go for relatively long periods (perhaps months or years) without operating. In a period of just weeks the baseline operators represented in Table 3 lost about 14 percent of their original SINCGARS proficiency levels on both the skills and knowledge exams.

Because a three-week period is a relatively short layoff compared to the periods of non-use that will probably occur for many SINCGARS users, a follow-on administration of the skills and knowledge exams was conducted after approximately six months for a subsample of operators from the artillery and cavalry groups. Only previous SINCGARS operators were used in the follow-on study.

The results for the artillery soldiers, presented in Table 3, depict an average loss for skills and knowledge of about 30 percent. By comparison, Table 4, which gives the results for the cavalry soldiers, depicts an average loss of about 8 percent. The discrepancy between the artillery and cavalry groups may be due to the fact that the cavalry soldiers had had 75 percent more SINCGARS experience.

Table 3

Skills and Knowledge Retention

(Artillery Soldiers after Six Months Layoff)

Test	N	Admin. #1[a]	Admin. #3[b]	% Change
Skills	6	90.1	65.4	-27.4
Knowledge	6	84.9	53.9	-36.5

[a]Percent correct after classroom training.
[b]Percent correct six months after MOT—total previous SINCGARS experience, including training: four weeks.

Table 4

Skills and Knowledge Retention

(Cavalry Soldiers after Six Months Layoff)

Test	N	Admin #1[a]	Admin #3[b]	% Change
Skills	14	82.3	74.2	-9.8
Knowledge	14	69.3	64.5	-6.9

[a]Percent correct after field exercise test (four weeks practice, not including training).
[b]Percent correct six months after MOT—total previous SINCGARS experience, including training: seven weeks.

Probably the most important point to make about the retention of skills and knowledge figures presented in Tables 1 through 4 is that the training periods for both the artillery and cavalry groups (but especially for the latter) were very intensive. The implication is that operators who have a more cursory contact with SINCGARS (as may be true of the majority of future users) will have a greater tendency to lose what they have learned unless they use the RT more or less continually.

DETAILED FINDINGS (Section 3: Design Considerations for Control Panel/Software/Operator Interface

Prior to the MOT, no extensive HF evaluation had been conducted for the SINCGARS-V. The HF evaluation team for the MOT therefore considered an evaluation of the operator/RT interface design (in addition to the normal operational evaluation) essential to providing a complete and rigorous assessment of the overall operability of the system. The interface design evaluation that ensued as part of the overall HF evaluation resulted in the development of several redesign suggestions that, if implemented, would make the operation of SINCGARS-V considerably simpler and more effective, especially from the standpoint of training and skill retention.

The details of the redesign suggestions, which were extensive, are not presented here. (The interested reader may refer to the OTEA Test Report cited earlier.) However, to indicate their nature and scope, the following list of 15 general interface criteria is presented. The redesign suggestions were developed to meet all of the criteria.

1. A large amount of space on a small, already crowed control panel has been devoted to electrical connectors. Because of the need to interface with peripheral equipment, this situation is difficult to change. However, any increased physical space would ease the operation of controls. It will be provided by eliminating or minimizing the use of selector switches and knobs.

2. Special dedicated function keys will be provided for frequently used functions and mode selections.

3. Keyboard keys will be raised and have molded shapes to promote tactile differentiation when the user is wearing gloves.

4. The panel data display and keyboard will be lighted so that all lettering is visible in low light conditions. The level of this lighting will self-adjust to ambient conditions but also be controllable by individual operators.

5. Function keys will be set out in logical rows with keys ordered for frequency of use or optimal sequence of operation.

6. Function selections related to the long term status of the RT (OFF, SQ ON, etc.), will be relegated to switch selections to prevent over cluttering the keyboard.

7. A display with at least two lines of six alpha characters each is desirable for providing adequate information flow from the system to the operator. No part of the display will be cut off by viewing angles up to 45 degrees from straight on. The character readouts will not be cryptic. (It is likely that the ADM display window would have to be widened to accommodate an acceptable two-line display.)

8. The display will provide feedback to the operator about system function, status, and data entry.

9. Keyboard executive functions (Enter, Clear, etc.) will have the same mechanization as personal calculators.

10. The communication variables (TRANSEC, lockout, and hopset) for all channels will be able to be ERFed as one continuous data stream to limit transmission time and exposure to jamming. The NCS time-of-day will continue to be included as part of the data stream.

11. The communications variable storage of the SINCGARS-V will be expanded to nine registers of data to provide more flexibility in channel allocation for SC and FH operations.

12. Provision of an NCS capability for ERFing SC frequency data (including cue frequencies) will simplify the net member operators' tasks and eliminate operator data entry errors when setting up or joining a net.

13. Cue operation will be confined to the "requesting" net member and the NCS (or alternate) to limit the distraction of cue signaling to other operators in the net.

14. An early warning of manpack battery voltage drop-off will be provided before it precipitates loss of communications. (This may require a different battery system.)

15. Channel scanning operation will be extended to the FH mode for net activity monitoring.

The design approach implied in the above criteria was accompanied by an analysis of operator actions in terms of the revised design concepts. The operational procedures were detailed in tables and compared with those for the existing SINCGARS-V ADM. The comparison was compiled for 39 normal operations, with the overall results showing the new design to require over one-third fewer keystrokes, and for some individual procedures over a 50 percent reduction (e.g., 71 percent for a cold start by the NCS).

The revisions presented were not to be taken as the "best" or as a "should be" design, but as a demonstration of the possibilities for design improvement. Any actual design revisions would, of course, be enhanced by the developer's engineering staff; they understand how the original design was engendered and could continue the process into new design approaches.

DISCUSSION AND CONCLUSION

Generally the RT operators who participated in the MOT were more favorable toward SINCGARS than their immediate supervisors, test directorate personnel, and the human factors evaluators. This can be explained at least partially as a matter of perspective. The operators received a relatively myopic exposure to SINCGARS and were for several weeks involved in a highly concentrated, intense exercise marked by new experiences and esprit de corps. Furthermore, it is likely that negative evaluations of the RT by the RT operators would be viewed by them as somewhat self-incriminating or self-deprecating, because it appeared to be difficult for many of the operators to maintain a "test orientation" (as opposed to a "mission orientation") toward the RT and the field exercise test. Their efforts were directed toward making the RT perform as well as possible, not toward the broader, long-term issues involved in evaluating the SINCGARS system. So, although it must be reported that most of the operators were generally satisfied with the SINCGARS ADM, several very serious deficiencies (both human factors and non-human factors) were discovered during the MOT. (In this regard, it should be noted that when a subsample of the operators were exposed to a modified version of the RT (Modified Advanced Development Model) one year later, they noted marked improvements in some important areas.)

Regarding human factors, the most serious general problem with the SINCGARS ADM is the complex nature of the operational procedures and the very heavy burden this would place on the training and maintenance of operating skills.

The radio is too complex for a person just to pick up and operate without relatively extensive training. To use the radio, one needs training beyond that necessary for the current inventory of Army radios. An operator must be familiar not only with the complexities and vagaries of the SINCGARS-V, but also with radio procedures and COMSEC equipment. Even if the skills can be trained, they will decay over time if they are not frequently used.

If military units dedicate particular personnel as radio operators, those operators, with continual use of the RT, would probably be able to maintain the necessary level of skill and knowledge. However, if an operator (especially an NCS operator) became a combat casualty, then the RT might have to be operated by someone without sufficient experience. In fact, the new operator might very well never have been SINCGARS trained. Even if trained, it is unlikely that skill and knowledge retention would be sufficient for satisfactory operation. The complexity of maintaining radio net operations with the SINCGARS ADM would create a high probability of total net failure under battle conditions if the net control operator were lost. Simplification, on the other hand, would allow continued operations by operators who were not classroom trained as net controllers. (It should also be pointed out here that operator problems experienced in the MOT would probably be manifested somewhat more acutely in the true operational environment. The reason is that the RT operators selected for the MOT had GT scores above the Army average, and those selected to be NCS operators had higher average GT's than those selected to be net members.)

The training requirement for the current model of the radio (ADM) would be so extensive that, without change, consideration would have to be given to the idea of creating a radio-operator MOS. However, the simplification of procedures and interface could reduce the training requirement substantially, so that, while the NCS operator may still need a certain amount of special training, the net member could probably be trained on the job. The RT itself should be (and can be) simplified for effective use by the expected user population.

The implications of the foregoing statements are both positive and negative. The cost of making changes involves delays in fielding the radio and adds dollars to the development project. But the changes would probably reduce life-cycle costs associated with training and usable life many times over the front-end investment.

Many of the human factors problems with the SINCGARS-V radio seem to be minor, with little apparent impact on mission performance. However, when the multitude of problems impinge on the operator concurrently, there is a synergistic and interactive effect that can lead to serious performance decrement. This fact leads unavoidably to the conclusion that the SINCGARS-V operating procedures and operator interface should be simplified.

The production of SINCGARS-V involves a substantial government investment for a large quantity of equipment that will be in general field use for many years. Therefore, every effort should be made to optimize the operator/RT interface to overcome the inadequacies documented by the MOT.